ART. V.—*On the Influence of Isomorphism in determining the Reactions that take place between Inorganic Compounds, and the Elements of Living Beings.* By JAMES BLAKE, M. D., Professor of Anatomy in the St. Louis University.

THE following memoir contains the results of a series of experiments, that have been undertaken with the view of ascertaining the laws that govern the reactions which take place between inorganic compounds, and the elements of living beings whilst still forming a part of the animal organism. The attention which has of late been bestowed on that interesting field of research, on which the phenomena presented by living beings appear to come into contact and to admit of explanation by the results furnished us in our experiments with inorganic matter, is a sufficient proof that physiologists are beginning to perceive that the branch of science which they cultivate, can no longer be advanced by a mere observance of the phenomena which take place in living beings, but that it is necessary that the torch of experimental investigation should be made to throw its light on the complicated processes going on in the living organism. There can be no doubt, also, that the discoveries which the microscope has revealed to us, must sooner or later meet with their application in solving many of the problems of life; but I am of opinion that of late far too much importance has been attached to this means of research, to the neglect of other paths which are more likely to lead nearer to the point, to the elucidation of which the labours of every physiologist should be directed, viz., the discovery of the laws which govern the reactions that take place in living beings. Although it cannot be denied that morphology must always constitute a most important branch of physiology, and perhaps even, as will be shown in this article, a more important branch than many are inclined to allow, yet we might as well hope to arrive at a knowledge of the properties of an inorganic compound, by studying the forms it assumes, as to attempt to explain the reactions that take place in living beings by simply investigating the form and grouping of their elements. The ready means which the possession of a microscope affords of making its possessor acquainted with new facts, seems to have enlisted all the cultivators of physiology into the ranks of the pure morphologists, and to such an extent has this been carried, that even our elementary treatises on physiology are almost wholly filled by morphological descriptions of the various tissues and fluids, to the neglect of those questions which bear on their chemical properties, and which must certainly exert a more important influence on the phenomena of life. Since the establishment of the law of isomorphism, there is no doubt that a careful investigation of the forms assumed by the different compounds of the same element, will throw much light on its relations to other bodies; but this of itself is not sufficient, and it is only by bringing it into contact with other substances as reagents, that we can arrive at a knowledge of its properties. The same remark will apply to the properties of the different substances which enter into the composition of living beings, for their elements, as well as the elements of inorganic compounds, must be possessed of properties which can only be discovered

by experimentally investigating the relations which take place between them and other forms of matter. The light which chemistry has recently thrown on some of the more interesting points of physiology, clearly points out the direction in which this branch of knowledge must be pursued, even did not a close analysis of the phenomena of life, by showing that they are dependent on certain changes which are constantly taking place in the elements of the body, lead us to study the chemical properties of these elements, in order to arrive at a knowledge of the laws which govern their changes. It is these considerations that have led me to institute a series of experiments, in which I have endeavoured to ascertain, with some degree of accuracy, the properties of the elements of which the living organism is composed, by bringing these elements, whilst still forming part of the living animal, into contact with certain re-agents, derived from inorganic compounds. My first experiments were made merely for the sake of observing the phenomena that followed the introduction of certain saline compounds into the blood; but the phenomena that presented themselves were, in some instances, so striking, as to lead me irresistibly to extend my researches much further than I had originally intended; and subsequently the indications of the existence of a new law governing the reaction between the elements of living beings and inorganic compounds, have induced me to carry on these researches so as to comprehend amongst the reagents I have used, compounds of twenty-eight of the simple elements. A moment's reflection on the problems to be solved by such researches, will suffice to show that experiments conducted with this class of substances, are more likely to furnish us with useful results, than those made with bodies derived from the vegetable or animal kingdom; although, by the striking effects produced by some of these substances on the animal economy, physiologists have mostly directed their attention to the reactions produced by them on the living body. By such a course of proceeding, however, we are employing reagents, with the composition and properties of which we are but imperfectly acquainted, to the neglect of those on the nature and properties of which chemistry has already thrown much light; for not only are we better acquainted with the more purely chemical properties of inorganic compounds, but their relation to heat, electricity and molecular polarity, has been, to a considerable extent, made out. The manner in which I have performed these experiments, has been to introduce a solution of the substance experimented with, into the veins or arteries of a living animal. The preparation necessary to do this, is not of a nature to disturb, to any extent, the functions of any organ; for it requires merely the introduction of a tube into a vein or artery. In most instances, the substances were introduced into the jugular vein; they then are brought into contact with the right cavities of the heart, thence with the pulmonary tissues, and the left cavities of the heart, whence they are circulated through the whole system. The phenomena principally observed, were those connected with the more important functions of the animal economy, as respiration, circulation, and the functions of the nervous system, and it has been principally, as regards these functions, that they have been noted.

The hemadynamometer has, by its use, greatly added to the facility and certainty of detecting any changes which take place in the circulation, and has revealed many interesting facts which must otherwise have escaped observation. If, for instance, a substance that had been in-

troduced into the blood gives rise to an obstruction in its passage through the pulmonary capillaries, this is instantly shown by the descent of the mercury in the instrument; for the supply of blood which reaches the left side of the heart, and the arteries, being cut off, the pressure of the blood in the arterial system is necessarily diminished, and this will take place in four or five seconds after the injection of the substance into the jugular vein. But if the substance used passes through the capillaries of the lungs, the next point at which we can trace any signs of its action is when it circulates over the parietes of the heart, or when it arrives at the capillary terminations of the coronary arteries. Should the reagent be of a nature to destroy the irritability of the heart, its motions are found to be arrested in from seven to ten seconds after it has been introduced into the vein; in this case, the pressure in the arterial system suddenly falls, and no oscillations are visible in the column of mercury. Should even the slightest change be produced in the action of the heart, by the passage of any substance over its parietes, this would be instantly indicated by a modification of the pressure in the arterial system. Should any effect be produced on the passage of the blood through the systemic capillaries, the pressure in the arteries instantly becomes increased if the systemic capillary circulation be obstructed, and diminished if the passage of the blood through these vessels is facilitated.

The effects produced upon the functions of the nervous system, and on respiration, are readily observed. In some cases in which a substance is arrested by the pulmonary capillaries, or when it suddenly stops the action of the heart, it is necessary to introduce it into the arterial system, in order to ascertain its effects on the brain and spinal cord.

In stating the facts that have been observed in these experiments, I shall not attempt to enter into details of the phenomena which characterize the action of each substance, but shall endeavour to present them in a tabular form, arranging the phenomena observed under the different heads before alluded to as connected with the modifications produced in the more important functions. I am aware that such a mode of bringing forward the facts I have to relate, must be attended with the inconvenience of omitting many details which it might be desirable to bring forward; but this I consider will be compensated by the facility it offers of comparing the effects of the various substances used. The arrangement I have followed in drawing up this table is not such as would be suggested by a consideration of the chemical properties of the substances employed, but is based on their physiological action, as ascertained by direct experiment. By the side of each substance experimented with, will be found the quantity generally required to arrest the action of the heart.

N. B. All the experiments were performed on dogs.

Substance experimented with, and the quantity required to arrest the action of the heart.	Action on the heart.	Effects on the nervous system.
1. Ammonia. Liquor ammonia, f. ℥ss. Hydrochlorate ammonia, ʒiss a ʒij. Nitrate ammonia, ʒiss a ʒij.	In small quantities they quicken the action of the heart, in larger doses they totally destroy it. Injected into the arteries, the action of the heart is arrested before respiratory movements cease.	Give rise to spasms resembling those produced by strychnia. Injected into the arteries, give rise to general spasm, and in very strong doses will arrest the respiratory movements before the action of the heart ceases.
2. Potassa and its salts. Caustic potassa 3 grs. Nitrate " 5 grs. Arseniate " 8 grs. Carbonate " 12 to 15 grs.	Resemble exactly the salts of ammonia.	Action on the nervous system not so marked as is the case with the salts of ammonia. Same phenomena follow their introduction into the arteries.
3. Salts of strontia. Nitrate of strontia, ʒss a ʒij, Chloride " ʒss a ʒij.	Heart's action rendered slower in about 10 seconds, and it becomes permanently slower and irregular. Irritability destroyed by larger doses; the ventricles appear to be more affected than the auricles.	No effects on the nervous system, except that they seem to favour the continuance of respiratory movements after the action of the heart has ceased. Injected into the arteries, even in large doses, they produce no marked effect on the nervous system.
4. Salts of baryta. Nitrate of baryta, 2 grs. Chloride of barium, 2 grs.	The same as the salts of strontia, but producing their effects in much smaller doses, the heart being quite paralyzed by 2 grs. of the salts in 12 seconds.	The same as the salts of strontia. Even when injected into the arteries, respiration continues for two minutes and a-half after the action of the heart has been arrested.
5. Salts of lead. Acetate of lead, Nitrate of lead.	Analogous to the salts of baryta, but the quantity required uncertain. Sometimes the irritability of the heart has been destroyed by 12 grs. of the acetate, in other experiments 3 drachms of the salt have been required to arrest its action.	More marked than with the salts of baryta. Respiration and sensibility continue for some minutes after the circulation has ceased.
6. Salts of silver. Acetate, Nitrate. It is only when the solution of the salt is sufficiently concentrated to produce a marked physical change in the blood, that the irritability of the heart is destroyed. Three or four grains of the salts will kill by their action on the lungs.	In small doses appear to augment the irritability of the heart. Rhythmical contractions continue 10 minutes after respiration has ceased, although death has taken place from asphyxia. In large doses the irritability of the heart is not increased.	Do not appear to exert any marked influence on the functions of the nervous system.
7. Salts of soda. Caustic soda, Chloride of sodium, Nitrate of soda, Carbonate of soda. When as much as three drachms of nitrate of soda have been injected into the veins, none of the functions appear affected, except that of respiration. The animal lived some hours, and died of asphyxia from effusion in the lungs.	Augment the irritability of the heart.	Do not affect the nervous system.

Effects on respiratory organs.	Effects on the capillary circulation.	General remarks.
Not affected.	Impede the passage of the blood through the systemic capillaries.	Neither ammonia nor its salts prevent, in small doses, the coagulation of the blood. Closely resembles some of the organic poisons in its effects on the nervous system, and in this respect differs from all other inorganic compounds.
Not affected.	The same as with the salts of ammonia. Pulmonary circulation not affected.	Coagulation of the blood favoured even by the caustic potassa, unless injected in very large doses, in which case the blood is rendered dark and grumous, as would be the case out of the body.
Respiratory movements always slightly affected immediately after their introduction into the veins; the lungs generally found redder than natural after death.	Passage of the blood through the pulmonary cavities impeded. Systemic capillaries not affected, except when introduced into the arteries, and then but slightly.	Muscular movements continue many minutes after death. The body has been pushed along by the extension of the hind legs; a quarter of an hour after death a *point d'appui* being afforded to the feet.
The same as the salts of strontia.	The same as the salts of strontia. Passage of the blood through the systemic capillaries rather more impeded.	Muscular movements have been observed to continue until forty minutes after death.
Marked effect on the lungs; after death these organs are found congested, and even during life a frothy secretion frequently fills the bronchial tubes and trachea, causing death by asphyxia.	The obstruction to the passage of the blood through the systemic and pulmonary capillaries is much greater than with the salts of baryta.	Muscular movements continue for some time after death. The same phenomenon had been noticed both by Haller and Orfila after the injection of the salts of lead into the veins. Blood coagulates imperfectly.
Lungs always much reddened, and effusion taking place in their tissue. Frothy secretion in the bronchial tubes when injected in small doses.	The passage of the blood through the systemic and pulmonary capillaries very much impeded. Two grains of the acetate injected into the arteries, caused an increase of pressure in the arterial system equal to a column of six inches of mercury.	Blood coagulates imperfectly.
The same as the salts of silver.	The same as the salts of silver.	Blood coagulates imperfectly.

Substance experimented with, and the quantity required to arrest the action of the heart.	Action on the heart.	Effects on the nervous system.
8. Salts of lime. Chloride of lime, 2 drs. Nitrate " 1¼ dr.	Heart's action rendered fluttering, then arrested by larger doses.	Slight spasms; powers of movement impaired; sensibility unaffected; vomiting.
9. Salts of magnesia. Sulphate of magnesia, ℥ij.	The same as the salts of lime.	Great prostration of strength; sensibility unimpaired; when injected into the arteries, proves fatal by its action on the nervous system; vomiting always takes place.
10. Salts of iron. Sulphate of iron, 30 to 40 grains.	Heart's action rendered slower by small doses, and then arrested.	Complete prostration; sensibility unaffected; vomiting.
11. Salts of zinc. Sulphate of zinc, 12 to 20 grains.	The same as the salts of iron.	The same as the salts of iron. Prostration noticed by Orfila.
12. Salts of manganese. Sulphate, 12 to 15 grs.	The same as the salts of iron.	The same as the salts of magnesia and iron.
13. Salts of copper. Sulphate, 16 to 20 grs.	The same as the salts of iron.	Prostration not quite so great as with the salts of iron and magnesia.
14. Salts of cadmium. Sulphate, 10 grs.	The same as the salts of zinc.	The same as the salts of magnesia.
15. Salts of nickel. Sulphate, 6 to 10 grs.	The same as the salts of zinc.	The same as the salts of magnesia.
16. Platinum. Chloride, 3 grs.	Heart's action rendered slower, and fluttering; irritability completely destroyed by three grains.	Slight prostration; no vomiting or convulsions. Injected into the arteries, it kills by its action on the nervous system.
17. Palladium. Chloride, 1 gr.	The same as platinum, but more poisonous.	The same as the salts of platinum.
18. Osmium. Double chloride of osmium and potassa, 2 grs.	Heart's action fluttering, not rendered slower.	The same as the salts of platinum.
19. Iridium. Double chloride of iridium and ammonia, 1 grain. (No salts, except the double salts both of iridium and osmium, are soluble in water.)	The same as the salts of platinum.	Prostration apparently from weakness of the circulation, the pressure in the arterial system being not more than equal to two inches of mercury.
20. Phosphorus. Phosphoric acid, a drachm to a drachm and a-half.	No marked effect on the heart, except when in quantities sufficient to change, in a marked degree, the physical properties of the blood.	Functions of the brain not affected; violent pain apparently in the abdomen.
21. Arsenic acid, a drachm to a drachm and a-half.	The same as phosphoric acid.	The same as phosphoric acid. Forty grains of the acid injected into the arteries, did not produce any marked effects on the functions of the brain.

Effects on respiratory organs.	Effects on the capillary circulation.	General remarks.
Slight spasmodic action of respiratory muscles.	Neither the systemic nor pulmonary capillary circulation affected.	Slight quivering of the muscles after death.
Slight dyspnœa.	The same as lime.	Blood coagulates.
Slight dyspnœa.	Appear to facilitate the passage of the blood through the systemic capillaries.	Blood remains quite fluid after death, so as to allow the complete subsidence of the red particles.
Slight dyspnœa.	The same as the salts of iron.	The action on the blood is the same as that of the salts of iron.
Slight dyspnœa.	The same as the salts of iron.	Blood did not coagulate.
Slight dyspnœa.	The same as the salts of iron.	The blood coagulates imperfectly; irritability of the voluntary muscles diminishes after death.
No effect.	The same as the salts of iron.	Blood remains fluid after death.
No effect.	The same as the salts of iron.	Blood remains fluid after death.
Respiration rendered intermittent in a marked degree; sometimes altogether suspended for one or two minutes, and then recommences, and this may take place many times. Lungs contain but very little blood after death.	Impedes the passage of the blood through the systemic capillaries. Pulmonary circulation not affected.	Slight muscular movements after death; blood apparently much affected, coagulates very imperfectly, and always of a dark maroon colour in the left cavities of the heart, although the action of the heart ceases before the respiratory movements.
The same as the salts of platinum. Lungs always anæmic after death.	Passage of the blood through the systemic capillaries much impeded, the pressure in the arterial system not diminishing until some minutes after the heart has ceased beating.	Action on the blood the same as the salts of platinum. The physical change produced in the blood is very great, considering the smallness of the quantity of the salt.
The same as the salts of platinum.	Systemic capillaries affected even when the salt is introduced into the veins.	Blood arterialized and coagulates. (I think the presence of potash in this salt cloaks the action of the osmium.)
Respiration intermittent; lungs anæmic.	Impedes the passage of the blood through the systemic capillaries when injected into the arteries.	The same action on the blood as the salts of platinum.
Dyspnœa; secretion of froth in the bronchi; lungs hepatized.	Obstructs the capillary circulation in the lungs.	Intestinal mucous membrane reddened. The blood has been found alkaline after as much as a drachm of glacial phosphoric acid had been injected into the veins; coagulation of the blood imperfect.
The same as phosphoric acid. Hepatization often partial; has been observed on three occasions to be confined to the left lobes.	Its action on the pulmonary capillaries does not appear to be quite so great as that of phosphoric acid.	The same action on the mucous membranes and on the blood as phosphoric acid.

Substance experimented with, and the quantity required to arrest the action of the heart.	Action on the heart.	Effects on the nervous system.
22. Arsenious acid.	Does not destroy the irritability of the heart even in a concentrated solution.	The same as arsenic and phosphoric acids.
23. Antimony. Tartrate, 40 grains.	The same as phosphoric acid.	Violent pain in the abdomen; voluntary movements slightly affected; no vomiting.
24. Sulphur. Sulphuric acid.	Increases the irritability of the heart.	Slight convulsions; no expression of pain.
25. Selenium. Selenic acid.	The same as sulphuric acid.	Movements of a spasmodic character, resembling chorea. Injected into the arteries, it kills by its action on the nervous system.
26. Chloric acid. 27. Hydrochloric acid. 28. Bromic acid. 29. Iodic acid. 30. Hydriodic acid. These substances so closely resemble each other in their action, that I consider it unnecessary to notice each separately. The quantity of the strong acids required to destroy life is, for the Chloric acid, 20 drops. Hydrochloric, 10 drops. Bromic acid, 10 grs. Iodic acid, 15 grs. Hydriodic acid, (sp. gr. 1.12) 3 drachms.	Increase in a marked degree the irritability of the ventricles, but they seem to weaken the irritability of the auricles. The ventricles continue irritable many minutes (10 to 20) after mechanical stimuli have ceased to affect the auricles; circulation will continue many minutes after respiration has ceased, even more vigorously than during life. The pressure in the arterial system has been found equal to a column of mercury of seven inches, eight or ten minutes after respiration had ceased, and, even when the pressure has sunk to two inches, it will again rise to five or six; the heart apparently receiving a fresh stimulus, although the animal has been, to all appearance, dead for some minutes.	Destroy the functions of the nervous system, particularly when injected into the arteries.

NOTE.—Having ascertained that all the salts of the same base produce analogous effects gated the action of one of the salts of each base.

A very superficial analysis of the results brought forward in the above table, will suffice to show how very different are the reactions which take place between the elements of living beings and these organic compounds, from those which we might have expected to be produced, from a consideration of the ordinary chemical properties of the re-agents employed. If, for example, we consider the action of some of these substances on the irritability of the heart, we find that by one powerful alkali (potash), it is suddenly destroyed; whilst by another (soda), it is increased; by some acids (the phosphoric and arsenic), it is deadened; by another class (the chloric), it is augmented in a remarkable degree; a strong caustic base (soda) augments it, whilst a comparatively chemically inert salt (the chloride of palladium), even in very small quantities, destroys it. A few grains of nitrate of potash arrest its movements in a few seconds, whilst more than twice the quantity of nitrate of silver only seems to increase its irritability. As regards the passage of the blood through the pulmonary

Effects on respiratory organs.	Effects on the capillary circulation.	General remarks.
The same as arsenic acid. The immediate cause of death would appear to be owing to its action on the pulmonary tissue.	The same as arsenic acid.	The same as arsenic acid.
The same as arsenious acid, but respiration rendered more irregular, *entre coupé*.	The same as arsenic acid.	Effects on gastro-intestinal mucous membrane, and on the blood, the same as those of arsenic acid.
Dyspnœa; secretion of fluid in the air passages; lungs hepatized.	The same as phosphoric acid.	Blood coagulates firmly.
The same as sulphuric acid.	The same as sulphuric acid.	Blood coagulates firmly.
The same as sulphuric acid.	Cause obstruction to the passage of the blood through the systemic and pulmonary capillaries.	The blood coagulates firmly.

when introduced into the blood, I have, in most instances, only experimentally investi-

capillaries, this certainly seems impeded by all acids; but we find that the same effect is produced by soda, and the salts of silver and lead. If, again, we consider the phenomena in connection with the supposed physiological action of the substance, we shall find quite as striking examples of the want of agreement between our preconceived notions, and the facts observed. We see an astringent substance (sulphate of iron), facilitating the passage of the blood through the capillaries, and preventing its coagulation, whilst an alkali (potash), causes the blood to coagulate more firmly, and at the same time affords an obstacle to its passage through the capillaries. We find arsenic exerting no marked effect on the tissues, even when injected in large quantities, whilst a much smaller quantity of carbonate of potash is rapidly fatal; we find the same substances (the salts of baryta), destroying the irritability of the heart, whilst they increase that of the voluntary muscles in a great degree (*this fact had been noticed by Haller, as regards the salts of lead*). Did these experiments only show the necessity of modi-

fying our notions, derived from the common properties of bodies, when we come to consider their action in the living organism, they would be of some use in clearing away many false views, which must exert an injurious influence on the study of physiological chemistry. But the results they furnish are not simply of a negative character; they do not merely prove that the reactions which take place in the living animal are not to be explained by the common chemical properties of matter,—but they point out a new law, which shows, that, under these circumstances, in which the ordinary properties appear to lose their application, a new and a more latent property of matter comes into play, and exerts its influence over a most extensive series of phenomena. A superficial view of the order in which the various substances experimented with, are arranged in the above tables, shows that they divide themselves into groups, each of which is distinguished by reactions not to be found in any other class. Thus we find potash and ammonia, agreeing very closely in the phenomena they give rise to; again we have strontia, baryta, and lead, all producing reactions nearly resembling each other, and all characterized by their influences on the muscular system. Soda and silver also agree very closely in the phenomena to which they give rise.

We then find a very large family of substances, including lime, magnesia, zinc, iron, copper, manganese, nickel and cadmium, all producing effects which resemble each other, and distinguished from all other bodies by their action on the nervous system.

Platinum, palladium, iridium and osmium, readily arrange themselves in a distinct class, agreeing as they do with each other in most of their reactions; another well-marked group is formed by phosphorus, arsenic and antimony. Selenium and sulphur are found closely to resemble each other in their reactions on the living organism; and between the remaining elements, chlorine, iodine and bromine, the most striking analogy exists in their physiological action.

The classes thus formed will be found to agree with those which are adopted by chemists in their arrangement of the different elements, according to their isomorphous relations, and the only conclusion to be derived from this interesting coincidence is, *that the physiological action of these substances depends upon some property they possess in connection with these isomorphous relations.*

The evidence on which this law is founded, will, I trust, be sufficient to ensure its reception. It has been arrived at by an experimental investigation of the physiological action of the compounds of the elements forming all the well-marked isomorphous groups, and in no instance has there been found an exception to it, for the apparent exception which has presented itself by the separation of soda and silver from the potash group, I conceive to be owing to these substances having been united into one group on insufficient grounds; for, whilst the isomorphous relations between soda and silver are well-marked, and also between potash and ammonia, it still admits of doubt, whether any well-marked relations exist between the two first and the two last substances.

But independently of the facts which the above experiments directly furnish of the existence of such a law, there are some collateral considerations which would add weight to the evidence they afford. It will be seen, on referring to the table, that the substances which appear to exert the least injurious effect, or to produce the slightest change in the animal economy, when introduced directly into the blood, are those which either exist in the body as constituents of some of its fluids or solids, or which have isomor-

phous relations with some of these; whilst, on the other hand, it will be found that those substances which have no isomorphous relations with the elements of the body, are those which are most fatal. The slight effects of arsenic and nitrate of silver, when injected into the veins, afford an example of the first proposition, whilst the very poisonous effects of palladium and baryta are instances of the last. It also appears to me interesting, under this point of view, that silver seems to possess the property of entering into the composition of the animal tissues, without destroying their vitality, or interfering with their functions; now this substance is isomorphous with soda, and I think it highly probable that it replaces it as an element in the composition of the tissues, in cases of coloration of the skin by the use of nitrate of silver. A consideration of the important part which form seems to exert in the phenomena of living beings, might lead us to expect that if, in the reactions that take place between their elements and inorganic compounds, any other property of matter should take a part different from its ordinary chemical properties, this might be a property connected with the form which even these inorganic elements have a tendency to assume. In the present imperfect state of our knowledge as regards isomorphism, it would be useless to speculate on what property connected with these relations, their physiological action depends; whether it is, for instance, through their relations to heat, or to electricity, or from analogy in their specific volumes, that we find isomorphous substances producing the same effects in the animal economy, or whether these effects are connected simply with the property which these substances have of assuming the same form. I think there is every probability that the law which governs the actions between inorganic elements and the elements of the blood and tissues, will be found to prevail in the reactions that are taking place between the different elements of the animal organism.

Having thus deduced the general law which appears to govern the reactions in which the elements of the living body, and these inorganic compounds, are concerned, I shall offer a few remarks on some of the more purely physiological phenomena that I have recorded in the above tables. If we investigate the facts connected with the modifications of the irritability of the heart, it will be seen that the greater number of the metallic salts appear to agree in destroying it; but to this the salts of silver form a marked exception: the alkaline bases and their salts (soda and potash), exert directly opposite reactions on its irritability, the one class increasing it, the other proving fatal to it. Of the earths, we find baryta acting as a powerful poison to it, whilst lime, except in large doses, exerts but slight influence over it.

The greater part of the acids evidently increase the irritability of the heart, but we are not justified in ascribing this to their properties as acids, when we find the phosphoric and arsenic deaden it, and, on the other hand, that it is increased by soda.*

If we compare the action which these substances exert on the heart,

* The action of the chlorine group of acids on the heart is very remarkable, for by their presence in the blood, they seem to supply, to a great extent, that stimulus which the oxygenation of the blood usually affords. This cannot be owing to the oxygen they contain, for the hydracids of these elements produce the same effects. In twenty experiments that have been performed with this class of substances, I have always found the irritability of the auricles to be diminished in a marked degree, whilst that of the ventricles is even to a more striking extent augmented; the ventricles are generally found beating rhythmically some minutes after the auricles have ceased to contract, and even after they are insensible to mechanical stimuli.

with their effects on the functions of the nervous system, we find that, in some instances in which the whole of the functions of the nervous system are suddenly annihilated, the irritability of the heart is much increased. On the other hand, we find substances which increase the action of the heart, exerting no perceptible action on the functions of the nervous system, whilst in other cases, they exert a deleterious influence on it. If we compare the action of these substances on the blood with their effects on the heart, we still find the same anomalies; those substances which favour the coagulation of the blood, in some instances increasing the irritability of the heart, in other instances destroying it, whilst by those substances which prevent the coagulation of the blood, we find the same opposite effects produced. These observations will show how little the action of these inorganic compounds on the heart is connected with their ordinary chemical properties: but there are one or two anomalies which present themselves when we consider the action of these compounds on the heart, in connection with their isomorphous relations;—for instance, there exists a great difference in the relative poisonous effects of the salts of baryta and those of strontia, two substances closely related as regards their isomorphous properties. Were these substances to be classed according to their action on the heart, we might be inclined to place the salts of strontia nearer to the salts of lime than to those of baryta; but here the action which the salts of strontia exercise on the general muscular tissue, refers it at once to the baryta group. There is also a great difference in the quantities required of the salts of magnesia, and those of nickel and cadmium, in order to destroy the irritability of the heart; but the difference is found only as regards the quantity, their action on the heart being perfectly analogous, and also the effects they produce on the nervous centres.

If we turn our attention to the phenomena recorded in the second column of the above tables, we find the same want of agreement between the physiological action of these substances, and their chemical action. Sometimes it is by an acid, sometimes by an alkali, that we find the functions of the nervous system destroyed; in some cases we see that considerable quantities of what are considered the most powerful poisons, can be brought into contact with the brain, without producing any marked symptom, whilst small quantities of some of the neutral salts are extremely fatal to it. The well-marked analogy that exists between the action of the whole of the magnesian class on the nervous system, although including bodies which differ so widely in their chemical and physical properties, affords a striking confirmation of the connection of the action of these substances with their isomorphous relations. As regards the general action of these inorganic substances on the nervous system, I find they differ from the poisons derived from the vegetable kingdom. The only substance amongst them whose action at all resembles that of the vegetable poisons, is ammonia—a substance which appears to form the link between organic and inorganic compounds, and which (or at least some compound of nitrogen, according to a remark of Liebig), enters into the composition of all vegetable poisons. The action of this substance offers the only anomaly as regards the classification of these substances, from their effects on the nervous system, according to their isomorphous relations. There are certain sources of fallacy which, in these experiments, may interfere with our appreciating with exactness the direct action of these substances on the nervous system, particularly the derangements that many of them produce in the circulation through the pulmonary and systemic capillaries. From both of these causes the brain becomes subject to increased pressure,

in the one case from venous congestion, and in the other from the accumulation of blood in the arterial system; the pressure caused by the obstruction of the pulmonary circulation, occurring, as it does, in the vein, seems to be much more injurious than when a far greater amount of pressure is supported by the arteries. I have seen the functions of the nervous system but little affected by a pressure in the arteries equal to ten inches of mercury, whilst in the venous system the pressure of an inch and a half, or two inches, is sufficient to arrest the functions of the nervous system. There is one fact in relation to the action of those substances on the nervous system which is worthy of note, viz., that nearly all those bodies which agree in producing great prostration, also agree in preventing the coagulation of the blood. In the action of these substances on the lungs, we find, as has already been remarked, some facts that might attach the phenomena observed to their ordinary chemical properties, for we see that all the acids act in the same way on the pulmonary tissue, or at least, that they give rise to the same changes in the lungs. But again, we see soda, and the salts of silver and lead, exerting the same influence. A closer connection appears to exist between the action of those substances on the lungs, and their influence in maintaining the irritability of the heart; in fact, most of them increase it, whilst all the substances which destroy its irritability, appear to pass through the lungs without affecting them. The only exception, furnished by the action of these bodies on the lungs, to the law which connects their physiological action with their isomorphous relations, is found in the action of the salts of lead, which agree with the salts of silver in the effects they produce on the pulmonary tissue. The effects produced upon the capillary circulation, both pulmonary and systemic, are capable of being observed with considerable accuracy. I have already remarked, that we find all the acids producing an impediment to the passage of the blood through the pulmonary capillaries, and some of these substances exert the same action on the systemic capillaries; whilst others, although they evidently impede the pulmonary circulation, pass through the systemic capillaries without producing the slightest obstruction.

We also find that many substances that pass readily through the capillaries of the lungs, cause great obstruction in the systemic capillaries. I am inclined to think that there are some substances that even facilitate the passage of the blood through the capillaries, although it is difficult to obtain any positive proof of this; nor am I able to state whether these bodies cause obstruction in the capillaries, owing to their rendering the blood physically incapable of passing through them, or whether the obstacle is caused by the contraction of the capillaries themselves.

The only class of facts that now remains to be noticed, are those that relate to the action of these substances on the blood, as ascertained by its more obvious physical characters. It might have been expected that, under this point of view, we should have found a close connection existing between the physical and chemical properties of the reagents employed, and the effects they produced; but such is not the case: for in no other class of phenomena do we find these substances acting so completely in accordance with their isomorphous relations.

The only exceptions observed are, that neither the salts of magnesia nor the salts of lime prevent the coagulation of the blood, although all the other members of the magnesian family produce this effect. The salts of lead also differ from those of baryta, in maintaining the blood fluid, and afford, in this respect, another instance of their analogy with the salts of soda and

silver. The fact which I have noticed, of the alkaline reaction of the blood after as much as a drachm of glacial phosphoric acid had been injected into the veins, affords a striking instance of the manner in which the chemical properties of a substance may be masked or changed when brought into contact with the living fluids and solids.

The action of the baryta group on the muscles of animal life, is in curious contrast with their action on the heart, the irritability of which they completely destroy, whilst the voluntary muscles continue contracting for many minutes after death.

It seems, from the foregoing observations, that, independently of the interest that many of the facts recorded may possess, in a physiological point of view, a closer analysis of the action of those substances on the different organs of the body, and on the blood, affords additional proof of the existence of the law connecting the physiological action of these inorganic compounds with their isomorphous relations. Considering the imperfect state of our knowledge as regards the isomorphous relations of the elements, it is surprising that more exceptions to this law have not presented themselves in so extended a series of experiments; and I have but little doubt, that those which have been remarked, will disappear before a more perfect knowledge of the molecular properties of matter, on which, I think, physiological experiments are destined to throw light.

ART. VI.—*An Analysis of the Cases of Delirium Tremens, admitted into the Bloomingdale Asylum for the Insane, from June 16th,* 1821, *to December 31st,* 1844. By PLINY EARLE, M.D., present Physician to the Asylum.

DURING the whole period of its existence, the Bloomingdale Asylum has been made the receptacle, not for cases of insanity proper, alone, but also for persons labouring under delirium tremens, as well as for some, who, although not attacked with this disease, were addicted to the habitual and excessive use of intoxicating liquors. These persons are not, strictly speaking, proper subjects for an asylum for the insane; but as there is no institution in the vicinity of New York particularly devoted to them, and no other place so well adapted to their treatment and temporary seclusion from the source of their disorder, this establishment almost necessarily became, in the hope of a reformation, their place of refuge.

The aggregate number of *cases* of this kind, admitted previously to the 31st December, 1844, is 594; of which 511 were males, and 83 females. But this number includes many readmissions of the same individuals. In the subjoined table these cases are arranged according to their several admissions and readmissions.

	Males.	Females.	Total.		Males.	Females.	Total.
First admission,	274	48	322	Ninth admission,	5	0	5
Second "	85	17	102	Tenth "	5	0	5
Third "	42	7	49	Eleventh "	5	0	5
Fourth "	29	4	33	Twelfth "	3	0	3
Fifth "	20	3	23	Thirteenth "	2	0	2
Sixth "	14	2	16	Fourteenth "	2	0	2
Seventh "	8	2	10	From 15th to 26th, each one admission,	12	0	12
Eighth "	5	0	5				
				Total	511	83	594